B345

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 862 395 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
07.04.2004 Bulletin 2004/15

(21) Application number: **96938674.7**

(22) Date of filing: **01.11.1996**

(51) Int Cl.7: **A61F 2/30**, A61F 2/32

(86) International application number:
PCT/US1996/017371

(87) International publication number:
WO 1997/016138 (09.05.1997 Gazette 1997/20)

(54) LOW-WEAR BALL AND CUP JOINT PROSTHESIS

KUGEL- UND PFANNE-GELENKPROTHESE MIT GERINGEM VERSCHLEISS

PROTHESE ARTICULAIRE A FAIBLE USURE

(84) Designated Contracting States:
BE DE DK ES FI FR GB GR IE IT LU NL PT SE

(30) Priority: **02.11.1995 US 617 P**

(43) Date of publication of application:
09.09.1998 Bulletin 1998/37

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EP 0 862 395 B1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The invention relates to implantable joint prostheses particularly adapted for the replacement of diseased or injured ball and cup joints.

[0002] Implantable ball and cup (socket) joints that are commercially available commonly consist of an implantable cup or socket that provides a generally hemispherical surface and that is made from a plastic such as ultra high molecular weight polyethylene, and a ball member that is made from a metal such as cobalt-chmme alloys. Usage of the implanted joint can result in significant wearing of the plastic cup portion, and this can in turn lead to such problems as wear particle-induced osteolysis which involves the development of large, soft tissue cysts where bone once existed. As a result of osteolysis, the bony support for both the cup and ball elements of a prosthesis may be weakened significantly, leading to loosening of these elements.

[0003] To reduce the amount of debris formed by wearing of a plastic surface, it would be desirable to make both the ball and cup articulating surfaces of a hard, wear-resistant substance such as a ceramic or a metal such as a cobalt-chrome alloy. The basic concept of utilizing metal-to-metal articulating surfaces for a prosthetic device is not new; reference is made to Walker, P.S., and B.L.Gold, *The Tribology (Friction, Lubrication and Wear) of All-Metal Artificial Hip Joints*, Wear 17:285-299, 1971, and to Notton, U.S. Patent 4,263,681; Hintermann, U.S. Patent 4,687,487; Sivash, U.S. Patent 3,943,576; and Shersher, U.S. Patent 3,859,669. The geometry of ball and cup prostheses also are discussed in Frey, U.S. Patent 4,031,570; Müller, U.S. Patent 4,784,662; and Fisher, PCT Publication No. WO 95/23566.

[0004] When the articulating surfaces of ball and cup joints are made of metal, however, wear continues to be a problem, it appears. There is an initial high rate of wear during the "wear in" period in which the ball or the cup or both are worn down to the point where they develop surfaces that fit with some snugness against one another, and as this occurs, the rate of wear gradually decreases. The small particles resulting particularly during the initial period of high wear are liberated into the synovial fluid that lubricates joint cavities and can be distributed into surrounding tissues; there is concern that this can lead to medical problems of the type encountered when polymeric surfaces are employed, as described above.

[0005] When the articulating surfaces of an all-metal ball and cup joint have worn down to the point where the wear rate has been reduced, commonly the wearing away process is found to have formed one or more ridges on the articulating surface of either the ball or the cup or both, the ridges delimiting the snug area or areas of contact between these surfaces. The ridges, while not interfering with normal articulating movement of the joint, none-the-less may accelerate wear during large range-of-motion movements and/or interfere with the entrainment of lubricating synovial fluid.

[0006] By carefully sculpting the articulating hard surfaces of ball and cup joints, the "wearing in" normally associated with such joints can be largely avoided, as can the formation of ridges on the ball or cup articulating surfaces.

[0007] The invention relates to an articulating ball and cup joint prosthesis for use between two normally articulating bones. The prosthesis comprises an articulating cup attachable to one of the bones and comprising a body having a generally hemispheric cavity provided with a first hard spheroidal articulating surface formed on a radius R_1. A second articulating member is provided having a generally ball-shaped body attachable to the other of the bones and having a second spheroidal hard articulating surface slidingly contacting the first articulating surface in an area of intimate contact, the second articulating surface being formed on a radius R_3.

[0008] "Area of intimate contact," as used herein, means that area in which the surfaces defined by the radii R_1 and R_3 are in contact where R_1 differs from R_3 by no more than 50 micrometers, desirably by no more than 25 micrometers, preferably by no more that 6 micrometers and most preferably by no more than 2 micrometers. The respective spheroidal surfaces of the first and second members are formed so that the area of intimate contact ranges from $0.12\pi R_3^2$ to $1.65\pi R_3^2$, and preferably from $0.2\pi R_3^2$ to $0.7\pi R_3^2$. Expressed in different terms, the area of intimate contact is the area of the spherical segment subtended by the solid angle ϕ formed on radius R_3 where ϕ ranges from 40 degrees to 160 degrees and preferably from 50 degrees to 100 degrees.

[0009] The respective spheroidal surfaces also provide a closely spaced but non contact area between them as they diverge immediately adjacent the area of intimate contact, the surfaces in the non contact area being characterized by the relationship $h = s^2/2R \pm 20\%$ in which "h" is the gap between the diverging surfaces of the ball and cup at a distance "s" from the edge of the area of intimate contact measured along the arc swept out by the radius R_1, and $R = (R_4R_2)/(R_4 - R_2)$ where R_4 and R_2 are the respective radii of the cup and the ball immediately adjacent the area of intimate contact. Expressed in different terms, for a location spaced from the area of intimate contact by the angle θ swept out by the radius R_3 away from the apex of the cup, the gap h is within 20% of the value of the expression $(R_1\theta)^2/2R$ in which R is as defined above and θ is expressed in radians. When θ is less than about 0.5 radians, the expression $(R_1\theta)^2/2R$ defines the gap h within plus or minus 3%.

Figure 1 is a broken-away schematic view in partial cross section of the articulating surfaces of a ball and cup joint

prosthesis of the invention with the cup member shown in cross-section;

Figure 2 is a perspective broken-away view of a hip prosthesis embodying a ball and cup joint prosthesis of the invention;

Figure 3 is a side view, in partial cross-section, of the cup portion of a prosthesis of the invention; and

Figure 4 is a schematic view of surfaces of a ball and cup joint prosthesis of the invention.

[0010] "Intimate contact area" means the sliding area of the hard articulating surfaces of the cup and ball in which R_1 differs from R_3 by no more than 50 micrometers, desirably by no more that 25 micrometers, preferably by no more than six micrometers, and most preferably by no more than two micrometers. On a microscopic level, any metal, ceramic, or other hard surface is somewhat rough and jagged, the surface having peaks and valleys. Reference is made to Mummery, L., *Surface Texture Analysis The Handbook*, Hommelwerke GmbH, 1992.

Preferably, the centerline average surface roughness of the articulating surfaces in the area of intimate contact is not greater than 0.1 micrometers and preferably not greater than 0.025 micrometers.

[0011] Referring first to Figure 2, the proximal portion of the human femur is shown at "F", and the adjacent acetabulum of the pelvis is shown as "B". As shown, a femoral prosthesis 10 is implanted in the proximal end of the intermedullary canal of the femur by well known surgical procedures, the femoral prosthesis comprising a stem 12 that is received in the intermedullary canal and an articulating ball 14 joined to the stem 12 by a connector such as the connecting neck 16, the neck positioning the ball at an angle to the axis of the femur to enable it to articulate in the cup. Shown at 18 in Figures 2 and 3 is an acetabular cup prosthesis which is implanted in the acetabulum by any of a number of similarly well known surgical procedures.

[0012] The surgical procedures employed in anchoring a femoral prosthesis and an acetabular cup prosthesis in the proximal end of the femur and in the acetabulum, respectively, have been widely reported. Commonly, the bony acetabulum is exposed and is surgically sculpted to receive a cup prosthesis such as that shown at 18 in Figure 3. The cup prosthesis may be provided with an outer convex surface 20 that is appropriately roughened or otherwise treated so as to promote good adhesion to bone cement or to promote ingrowth of bony tissue in the event that cement is not employed. Screws or other attachments may be employed to more securely anchor the cup to the acetabulum. In Figure 3, fins 22 are positioned on the outer rim of the cup and become embedded in the hard bony rim of the acetabulum as the cup is forced into place. As mentioned above, bone cement commonly is employed to anchor the cup to the bony acetabulum.

[0013] The cup shown in Figure 3 is depicted as being of metal and having a metallic inner articulating surface 24. However, the cup may consist of several elements. For example, an outer shell similar to that shown in Figure 3 may be provided for attachment to the bony acetabulum, and an inner generally hemispheric shell may be carried by the outer shell, the inner shell having a concave, generally spheroidal hard articulating surface.

[0014] Referring to the femoral prosthesis 10 of Figure 2, the intermedullary canal "C" of the femur commonly is surgically prepared to receive the stem 12 of the prosthesis, and the stem may be either cemented in place using typical bone cement or may be provided with an exterior surface which is tightly received in the intermedullary canal and which promotes and supports bone growth. The ball 14 is attached by means of the neck 16 to the stem and is provided with a hard outer surface 25 (Figure 1) which is carefully formed and configured to articulate with the interior hard articulating surface 24 of the cup. The invention relates to the nature of the articulating interaction between the spheroidal articulating hard surfaces of the ball and cup, and it is to this interaction that we now turn.

[0015] Referring now to Figure 1, the ball 14 and cup 18 are shown in articulating contact with one another, and it will be understood that the differences in curvatures of the confronting surfaces of the ball and cup in this figure and also in Figure 4 have been exaggerated for ease of understanding. The area of contact within the solid angle ϕ is referred to herein as the "area of intimate contact", and within this area, the surface of the cup is formed on radius R, and the surface of the ball is formed on radius R_3. Beyond the area of intimate contact, the surfaces of the ball and cup diverge. Immediately adjacent the area of intimate contact, the radius of the ball is indicated as R_2 and the radius of the cup as R_4.

[0016] Within the area of intimate contact, R_1 differs from R_3 by no more than 50 micrometers, desirably by no more than 25 micrometers, preferably by no more than 6 micrometers, and most preferably by no more than 2 micrometers. The area of contact subtended by the solid angle ϕ ranges from $0.12\pi R_3^2$ to $1.65\pi R_3^2$, and preferably from $0.2\pi R_3^2$ to $0.7\pi R_3^2$, as measured when the ball is gently received within the cup (that is, without significant compressive loading between the ball and cup). As discussed in greater detail below, the articulating surfaces of the ball and cup desirably have certain maximum surface roughnesses, and it will be understood that the radii R_1, R_2, R_3 and R_4 are measured to the surfaces of the ball and cup as defined by the tips of the surface asperities as measured by a standard coordinate measuring device such as a Sheffield-Bendix Formax model 6060 instrument using a 1.6 mm carbide ball as a probe tip. Such an area of intimate contact would not exist in a conventional metal-to-metal ball and cup prosthesis with the radius of curvature of the ball slightly smaller than that of the cup. As mentioned previously, with conventional metal-to-metal prostheses, high initial wear occurs, and a zone develops in which the surfaces fit with some snugness and

have about the same radii of curvature, the zone being bounded by ridges. By providing an area of intimate contact as described herein, such initial wear largely can be avoided. With conventional metal- to-metal implants, most of the wear occurs in the first year or two following implantation. By largely avoiding this initial wear, we may reduce the total wear significantly over the life of the implant.

[0017] For ease of understanding, the area of intimate contact shown in Figure 1 has its center at the apex A of the ball and cup. From Figure 2, it will be understood that the actual compressive load axis between the ball and cup does not necessarily pass through the apexes of the ball and cup, but instead is inclined from the vertical (assuming a standing position) by an angle A ranging from about 15° to about 35°. It is important that the area of intimate contact as described and defined above be intersected by the load axis through all normal movements of the femur with respect to the pelvis. The area of intimate contact is shown in Figure 1 as extending through the angle ϕ uniformly about the surface of the ball. Desirably, the angle ϕ is large enough to accommodate various alignments of the ball and cup and the position of the load axis so that the latter passes through the area of intimate contact. It may be desirable to shift the axis extending through the center of the area of intimate contact slightly away from the apex of the ball or cup or both so that the area of intimate contact is not symmetric about the apex of the ball or cup but rather is oriented to better contain the shifting load axis.

[0018] The articulating hard surfaces of the ball and socket each preferably are made from a hard metal such as cobalt-chrome alloys. Metals such as titanium and titanium alloys preferably are avoided because of their low galling resistance. Ceramic materials also may be used. References herein to "hard" surfaces should be understood to refer to surfaces having surface hardness values not less than about 170 Knoop. The Knoop hardness number results from the quotient: load applied to a pyramid body/indentation area. The articulating surfaces may be carefully shaped by known superfinishing grinding or lapping processes. Articulating metal surfaces may be hardened by known methods including ion bombardment and the like. Polishing of the resulting surfaces can be done in the usual fashion with a superfinishing machine using a very fine abrasive, care being taken to preserve the congruency of the articulating surfaces of the ball and cup. The shaped surfaces may also be coated with a hard coating such as a diamond-like coating or with a nitride such as titanium nitride. When the articulating surfaces are of metal, it is preferred to employ different metals, or different alloys of similar metals, for the respective surfaces, with the result that the levels of wear resistance of the two materials are different. For example, the surface of the ball may be of a low carbon cobalt-chrome alloy and the surface of the cup of a high carbon cobalt-chrome alloy.

[0019] Also important to the present invention is the nature of the confronting surfaces of the ball and cup in the area immediately adjacent the area of intimate contact. In this area, referred to herein as a "non contact" area, the radius on which the surface of the ball is formed is slightly less than that of the cup. It is desired that the surfaces of the cup and ball diverge from one another gradually in this non-contact area, and it is believed that the very gradual divergence of these surfaces contributes to the ease with which synovial fluid is received between the cup and ball surfaces in the area of intimate contact and to permit the avoidance of ridges which could contribute to increased wear.

[0020] Figure 1 depicts the interior of the cup as being spherical and the ball being formed on the same radius as the cup at the center of the area of intimate contact and a smaller radius toward its equator, and this is the preferred embodiment. The ball may be made spherical instead, and its surface may be formed on the same radius as the cup at the center of the area of intimate contact and may be formed on a larger radius outside the area of intimate contact as the equator is approached. For that matter, outside the area of intimate contact, the radius of the ball may be decreased to a smaller value and the radius of the cup may be increase to a larger value as the equator is approached, so long as the relationship between the gap and the angle θ is substantially as described above. In the latter case, distance s would be located on the arc swept out by the radius R_1, and would lie between the confronting surfaces of the ball and cup. In any event, in order to better avoid the formation of ridges adjacent the area of intimate contact, the radii R_2 and R_4 each preferably has its origin along a line passing through both the origin of the radius R, and the edge of the area of intimate contact.

[0021] When, as in Figure 1, the interior surface of the cup is spherical ($R_1 = R_4$) and the surface of the ball outside the area of intimate contact is formed on a lesser radius, the gap "h" between confronting surfaces of the ball and cup at a distance s from the edge of the area of intimate contact measured along the arc swept out by the radius R_1; that is, along the curved surface of the cup away from its apex, is within 20% of the value given by the expression $s^2/2R$ in which the effective radius $R = (R_4R_2)/(R_4 - R_2)$ where R_2 and R_4 are the radii of the ball and of the cup, respectively, immediately adjacent the area of intimate contact. Phrased another way, for a given position on the surface of the cup spaced from the area of intimate contact by the angle θ (as shown in Figure 1) as the angle swept out by the radius R_1 away from the area of intimate contact, the gap h is within 20% of the value of the approximate expression $(R_1\theta)^2/2R$ in which R is as defined above. When θ is less than about 0.5 radians, the expression $(R_1\theta)^2/2R$ defines the gap h within plus or minus 3%.

[0022] Similarly, when the exterior surface of the ball is spherical ($R_2 = R_3$) and the surface of the cup outside the area of intimate contact is formed on a larger radius, the gap h between confronting surfaces of the ball and cup at a distance s from the edge of the area of intimate contact measured along the arc swept out by the radius R_3, that is,

along the curved surface of the ball away from its apex is within 20% of the value given by the expression $s^2/2R$ in which R is as given above. Phrased another way, for a given position on the surface of the cup spaced from the area of intimate contact by the angle θ (as shown in Figure 1) as the angle swept out by the radius R_3 away from the area of intimate contact, the gap h is within 20% of the value of the approximate expression $(R_3\theta)^2/2R$ in which R is as defined above and θ is expressed in radians. When θ is less than about 0.5 radians, the expression $(R_3\theta)^2/2R$ defines the gap h within plus or minus 3%.

[0023] Since, in the area of intimate contact, R_1 and R_3 are essentially equal, the expressions $(R_3\theta)^2/2R$ and $(R_1\theta)^2/2R$ are essentially equivalent and can be represented by the latter expression. Although this expression is not precise, it closely approximates the gap h measured along a line extending through the origin of R_1 and the confronting surfaces of the ball and cup, and is useful not only when $R_1 = R_4$ or $R_2 = R_3$, but also when neither of these expressions apply, that is, when the surfaces of the cup and ball outside the area of intimate contact are formed on radii different from the cup and ball radii within the area of intimate contact.

[0024] Thus, it should be understood that the confronting surfaces of the ball and cup diverge quite gradually away from the area of intimate contact, and ridges on the cup or ball are avoided. The nature of the surfaces in the area of intimate contact is such that the surfaces slide over one another with a small amount of wear distributed over the area of intimate contact. It is beneficial to have a large, well lubricated area of intimate contact.

The rate at which the surfaces diverge outside of the area of intimate contact is a function of the effective radius R, as given above. R desirably is in the range of 1 to 14 meters, and preferably in the range of 3 to 10 meters.

[0025] Figure 4 illustrates articulating surfaces of a cup and ball in the situation where the surfaces of the cup and ball outside the area of intimate contact are formed on radii different from the cup and ball radii within the area of intimate contact, positions on the cup and ball being located in an X-Y coordinate system having its origin at the center of the area of intimate contact with the X axis perpendicular to the contacting surfaces of the ball and cup at the center of the area on intimate contact. Here, the gap "g" is measured at any given value of X in the non contact area, that is, parallel to the Y axis, and is given by the expression

$$g = (R_2 - R_4)(1 - D^2)^{1/2} + [R_4^2 - (X^* - R_4D)^2]^{1/2} - [R_2^2 - (X^* - R_2D)^2]^{1/2},$$

where $X^* = X - R_1(1 - D)$ and $D = \cos(\phi/2)$.

[0026] Surface roughness of the articulating surfaces also has an influence on wear. The centerline average surface roughness of both the ball and cup articulating surfaces, as measured by a profile measuring machine such as a Sheffield profilometer, is not greater than 0.1 micrometers and preferably is not greater than 0.025 micrometers. With ceramic materials, a surface roughness of 0.0125 micrometers or less may be obtained and is preferred. As with any metal surface, the articulating surfaces of the ball and cup consist of a series of peaks and valleys when viewed at a microscopic level, and when microscopically rough surfaces rub against one another, some wear will occur as the peaks of the respective surfaces encounter one another. In accordance with the present invention, however, it is not enough that the respective articulating surfaces have smooth surfaces. It is also required that the area of intimate contact of these surfaces be in the range of $0.12\pi R_3^2$ to $1.65\pi R_3^2$. Desirably, the confronting surfaces of the cup and ball adjacent the area of intimate contact diverge in a ridge-free and gradual manner so as to promote lubricant entrainment.

[0027] As a result of the invention, the articulating hard surfaces of the ball and cup joint wear very little, thereby releasing little in the way of harmful debris into the joint space.

[0028] While a preferred embodiment of the present invention has been described, it should be understood that various changes, adaptations and modifications may be made therein without departing from the scope of the appended claims.

Claims

1. An articulating joint prosthesis for use between two normally articulating bones, comprising:

   an articulating cup member (18) attachable to one of the bones and comprising a body having a generally hemispheric cavity provided with a spheroidal internal surface including a first spheroidal articulating surface formed on a radius R_1, the surface hardness value being not less than 170 Knoop,

   an articulating ball member (14) attachable to the other of the bones and having a generally ball-shaped body provided with a spheroidal surface including a second spheroidal articulating surface formed on a radius R_3, the surface hardness value being not less than 170 Knoop, and slidingly contacting the first articulating surface

in an area of intimate contact

characterised in that R_1 differs from R_3 by no more than 50 micrometers, and **in that** the respective first and second articulating surfaces are configured so that the area of intimate contact ranges from $0.12\pi R_3^2$ to $1.65\pi R_3^2$.

2. The articulating joint prosthesis of Claim 1, wherein the respective first and second spheroidal surfaces are configured so that the area of intimate contact ranges from $0.2\pi R_3^2$ to $0.7\pi R_3^2$.

3. An articulating joint prosthesis according to Claim 1 or Claim 2, in which the ball (14) and cup (18) include gradually diverging surfaces outside the area of intimate contact formed respectively on radii R_2 and R_4, and in which the respective first and second spheroidal surfaces diverging gradually immediately adjacent the area of intimate contact provide a non contact area between the spheroidal surfaces are **characterized by** the relationship at a position X

$$g = (R_2-R_4)(1-D^2)^{½}+[R_4^2-(X^*-R_4D)^2]^{½}-[R_2^2-(X^*-R_2D)^2]^{½},$$

where $X^* = X-R_1(1-D)$, $D = \cos(\phi/2)$, and $R = (R_4R_2)/(R_4-R_2)$, and wherein X is located on an X-Y coordinate system having its origin at the center of the area of intimate contact with the X axis perpendicular to the contacting surfaces of the ball (14) and cup (18) at the center of the area on intimate contact, and where g is the gap between the spheroidal surfaces in the non contact area measured parallel to the Y axis at the position X, wherein R, in meters, ranges from 1 to 14, and wherein the first and second articulating surfaces in the area of intimate contact are each **characterized by** a centerline average surface roughness of not greater than 0.1 micrometers.

4. The articulating joint prosthesis of Claim 1 or Claim 2, wherein respective first and second spheroidal surfaces diverge immediately adjacent the area of intimate contact to provide a closely spaced but non contact area between the spheroidal surfaces, the configuration of the surfaces in the non contact area being **characterized by** the relationship $h = (R_1\theta)^2/2R \pm 20\%$ in which h is the gap between the diverging surfaces at a location spaced away from the area of intimate contact by the angle θ swept out by the radius R_3, and $R = (R_4R_2)/R_4-R_2)$ where R_2 and R_4 are the radii of the spheroidal surfaces of the ball and cup, respectively, immediately adjacent the area of intimate contact.

5. The prosthesis of Claim 3 or Claim 4, wherein R_2 is smaller than R_3.

6. The prosthesis of Claim 3 or Claim 4, wherein R_4 is greater than R_1.

7. The prosthesis of Claim 3 or Claim 4, wherein $R_1 = R_4$.

8. The prosthesis of Claim 3 or Claim 4, wherein $R_2 = R_3$.

9. The prosthesis of any one of the preceding claims, wherein the first and second articulating surfaces in the area of intimate contact are each **characterized by** a centerline average surface roughness of not greater than 0.1 micrometers.

10. The prosthesis of Claim 9, wherein the first and second articulating surfaces in the area of intimate contact are each **characterized by** a centerline average surface roughness of not greater than 0.025 micrometers.

11. The prosthesis of any one of the preceding claims, wherein one of the articulating surfaces of the ball or cup is formed on a constant radius both within and outside the area of intimate contact and the other surface is not.

12. The prosthesis of Claim 4 wherein R, in meters, ranges from 1 to 14.

13. The prosthesis of Claim 4 or any claim dependent thereon, wherein the configuration of the surfaces in the non contact area at a location spaced away from the area of intimate contact by said angle θ where θ is less than 0.5 radians is **characterized by** the relationship $h = (R_1\theta)^2/2R \pm 3\%$.

14. The prosthesis of Claim 4 or any claim dependent thereon, wherein the surfaces in the non contact area at a position X are **characterized by** the relationship

$$g = (R_2-R_4)(1-D^2)^{½}+[R_4{}^2-(X^*-R_4D)^2]^{½}-[R_2{}^2-(X^*-R_2D)^2]^{½},$$

where $X^* = X-R_1(1-D)$, $D = \cos(\phi/2)$, and $R = (R_4R_2)/(R_4-R_2)$, and wherein X, Y is located on an X-Y coordinate system having its origin at the center of the area of intimate contact with the X axis perpendicular to the contacting surfaces of the ball and cup at the center of the area on intimate contact, and where g is the gap between said spheroidal surfaces in the non contact area measured parallel to the Y axis at said position X.

Patentansprüche

1. Artikulierende Gelenkprothese zur Verwendung zwischen zwei normal artikulierenden Knochen mit:

   einem artikulierenden Pfannenteil (18), das an einem der Knochen ansetzbar ist und einen Körper aufweist, der eine allgemein halbkugelförmige Höhlung hat, die mit einer sphäroidalen Innenfläche versehen ist, die eine erste sphäroidale artikulierende Oberfläche aufweist, die auf einem Radius R_1 gebildet ist, wobei der Oberflächenhärtewert mindestens 170 Knoop beträgt,
   einem artikulierenden Kugelteil (14), das am anderen der Knochen ansetzbar ist und einen allgemein kugelförmigen Körper hat, der mit einer sphäroidalen Oberfläche versehen ist, die eine zweite sphäroidale artikulierende Oberfläche aufweist, die auf einem Radius R_3 gebildet ist, wobei der Oberflächenhärtewert mindestens 170 Knoop beträgt, und die erste artikulierende Oberfläche in einer innigen Kontaktfläche gleitend kontaktiert, **dadurch gekennzeichnet, daß** sich R_1 von R_3 um höchstens 50 Mikrometer unterscheidet, und dadurch, daß die jeweilige erste und zweite artikulierende Oberfläche so konfiguriert sind, daß die innige Kontaktfläche im Bereich von $0{,}12\pi R_3^2$ bis $1{,}65\pi R_3^2$ liegt.

2. Artikulierende Gelenkprothese nach Anspruch 1, wobei die jeweilige erste und zweite sphäroidale Oberfläche so konfiguriert sind, daß die innige Kontaktfläche im Bereich von $0{,}2\pi R_3^2$ bis $0{,}7\pi R_3^2$ liegt.

3. Artikulierende Gelenkprothese nach Anspruch 1 oder Anspruch 2, wobei die Kugel (14) und Pfanne (18) allmählich divergierende Oberflächen außerhalb der innigen Kontaktfläche aufweisen, die auf einem Radius R_2 bzw. R_4 gebildet sind, und wobei die jeweilige erste und zweite sphäroidale Oberfläche, die unmittelbar benachbart zur innigen Kontaktfläche allmählich divergieren, eine kontaktfreie Fläche zwischen den sphäroidalen Oberflächen bilden und durch die Beziehung an einer Position X

$$g = (R_2-R_4)\,(1-D^2)^{½}+[R_4{}^2-(X^*-R_4D)^2]^{½}-[R_2{}^2-(X^*-R_2D)^2]^{½}$$

   gekennzeichnet sind, in der $X^* = X-R_1(1-D)$, $D = \cos(\phi/2)$ und $R = (R_4R_2)/(R_4-R_2)$ ist, und wobei X in einem X-Y-Koordinatensystem mit seinem Ursprung in der Mitte der innigen Kontaktfläche liegt, wobei die X-Achse senkrecht zu den kontaktierenden Oberflächen der Kugel (14) und Pfanne (18) in der Mitte der innigen Kontaktfläche ist, und in der g der Spalt zwischen den sphäroidalen Oberflächen in der kontaktfreien Fläche in der Messung parallel zur Y-Achse an der Position X ist, wobei R im Bereich von 1 bis 14 Metern liegt und wobei die erste und zweite artikulierende Oberfläche in der innigen Kontaktfläche jeweils durch eine arithmetische Mittenrauhtiefe von höchstens 0,1 Mikrometer gekennzeichnet sind.

4. Artikulierende Gelenkprothese nach Anspruch 1 oder Anspruch 2, wobei eine jeweilige erste und zweite sphäroidale Oberfläche unmittelbar benachbart zur innigen Kontaktfläche divergieren, um eine eng beabstandete, aber kontaktfreie Fläche zwischen den sphäroidalen Oberflächen zu bilden, wobei die Konfiguration der Oberflächen in der kontaktfreien Fläche durch die Beziehung $h = (R_1\theta)^2/2R \pm 20$ % gekennzeichnet ist, in der h der Spalt zwischen den divergierenden Oberflächen an einer Stelle ist, die von der innigen Kontaktfläche weg um den durch den Radius R_3 überstrichenen Winkel θ beabstandet ist, und $R = (R_4R_2)/(R_4-R_2)$ ist, wobei R_2 und R_4 die Radien der sphäroidalen Oberflächen der Kugel bzw. Pfanne unmittelbar benachbart zur innigen Kontaktfläche sind.

5. Prothese nach Anspruch 3 oder Anspruch 4, wobei R_2 kleiner als R_3 ist.

6. Prothese nach Anspruch 3 oder Anspruch 4, wobei R_4 größer als R_1 ist.

7. Prothese nach Anspruch 3 oder Anspruch 4, wobei $R_1 = R_4$ ist.

8. Prothese nach Anspruch 3 oder Anspruch 4, wobei $R_2 = R_3$ ist.

9. Prothese nach einem der vorstehenden Ansprüche, wobei die erste und zweite artikulierende Oberfläche in der innigen Kontaktfläche jeweils durch eine arithmetische Mittenrauhtiefe von höchstens 0,1 Mikrometer gekennzeichnet sind.

10. Prothese nach Anspruch 9, wobei die erste und zweite artikulierende Oberfläche in der innigen Kontaktfläche jeweils durch eine arithmetische Mittenrauhtiefe von höchstens 0,025 Mikrometern gekennzeichnet sind.

11. Prothese nach einem der vorstehenden Ansprüche, wobei eine der artikulierenden Oberflächen der Kugel oder Pfanne auf einem konstanten Radius sowohl innerhalb als auch außerhalb der innigen Kontaktfläche gebildet ist und die andere nicht.

12. Prothese nach Anspruch 4, wobei R im Bereich von 1 bis 14 Metern liegt.

13. Prothese nach Anspruch 4 oder einem Anspruch in Abhängigkeit davon, wobei die Konfiguration der Oberflächen in der kontaktfreien Fläche an einer von der innigen Kontaktfläche um den Winkel θ beabstandeten Stelle, wobei θ kleiner als 0,5 Radiant ist, durch die Beziehung $h = (R_1\theta)^2/2R \pm 3\ \%$ gekennzeichnet ist.

14. Prothese nach Anspruch 4 oder einem Anspruch in Abhängigkeit davon, wobei die Oberflächen in der kontaktfreien Fläche an einer Position X durch die Beziehung

$$g = (R_2-R_4)\,(1-D^2)^{½}+[R_4{}^2-(X^*-R_4D)^2]^{½}-[R_2{}^2-(X^*-R_2D)^2]^{½}$$

gekennzeichnet sind, in der $X^* = X-R_1(1-D)$, $D = \cos(\phi/2)$ und $R = (R_4R_2)/(R_4-R_2)$ ist, und wobei X, Y in einem X-Y-Koordinatensystem mit seinem Ursprung in der Mitte der innigen Kontaktfläche liegt, wobei die X-Achse senkrecht zu den kontaktierenden Oberflächen der Kugel und Pfanne in der Mitte der innigen Kontaktfläche ist, und in der g der Spalt zwischen den sphäroidalen Oberflächen in der kontaktfreien Fläche gemessen parallel zur Y-Achse an der Position X ist.

Revendications

1. Prothèse de jointure articulée destinée à être utilisée entre deux os normalement articulés, comprenant :

   un élément en forme de coupelle d'articulation (18) qui peut être fixé à l'un des os et comprenant un corps comportant une cavité généralement hémisphérique pourvue d'une surface interne sphéroïdale comprenant une première surface d'articulation sphéroïdale formée sur un rayon R_1, la valeur de dureté de la surface n'étant pas inférieure à 170 Knoop,

   un élément d'articulation en forme de bille (14) qui peut être fixé à l'autre des os et comportant un corps généralement en forme de bille pourvu d'une surface sphéroïdale comprenant une deuxième surface d'articulation sphéroïdale formée sur un rayon R_3, la valeur de dureté de la surface n'étant pas inférieure à 170 Knoop, et en contact de glissement avec la première surface d'articulation dans une région de contact intime **caractérisée en ce que** R_1 ne diffère pas de plus de 50 microns de R_3 et **en ce que** les première et deuxième surfaces d'articulation respectives sont configurées de sorte que la région de contact intime soit comprise entre $0{,}12\,\pi\,R_3^2$ et $1{,}65\,\pi\,R_3^2$.

2. Prothèse de jointure articulée selon la revendication 1, dans laquelle les première et deuxième surfaces sphéroïdales respectives sont configurées de sorte que la région de contact intime soit comprise entre $0{,}2\,\pi\,R_3^2$ et $0{,}7\,\pi\,R_3^2$.

3. Prothèse de jointure articulée selon la revendication 1 ou la revendication 2, dans laquelle la bille (14) et la coupelle (18) comprennent des surfaces graduellement divergentes à l'extérieur de la région de contact intime formées respectivement sur les rayons R_2 et R_4, et dans laquelle les première et deuxième surfaces sphéroïdales respectives graduellement divergentes à proximité immédiate de la région de contact intime réalisent une région sans contact entre les surfaces sphéroïdales et sont **caractérisées par** la relation à une position X

$$g = (R_2-R_4)(1-D^2)^{½}+[R_4^{\,2}-(X^*-R_4D)^2]^{½}-[R_2^{\,2}-(X^*-R_2D)^2]^{½},$$

où $X^* = X-R_1(1-D)$, $D = \cos(\phi/2)$ et $R = (R_4R_2)/(R_4-R_2)$, et dans laquelle X est situé dans un système de coordonnées X-Y ayant son origine au centre de la région de contact intime avec l'axe X perpendiculaire aux surfaces en contact de la bille (14) et de la coupelle (18) au centre de la région de contact intime, et où g est l'espace entre les surfaces sphéroïdales dans la région sans contact mesuré parallèlement à l'axe Y à la position X, dans laquelle R, en mètres, est compris entre 1 et 14, et dans laquelle les première et deuxième surfaces d'articulation dans la région de contact intime sont caractérisées chacune par une rugosité de surface moyenne centrale ne dépassant pas 0,1 micron.

4. Prothèse de jointure articulée selon la revendication 1 ou la revendication 2, dans laquelle des première et deuxième surfaces sphéroïdales respectives divergent à proximité immédiate de la région de contact intime afin de réaliser une région étroitement espacée mais sans contact entre les surfaces sphéroïdales, la configuration des surfaces dans la région sans contact étant **caractérisée par** la relation $h = (R_1\theta)^2/2R \pm 20\ \%$ dans laquelle h est l'espace entre les surfaces divergentes à un emplacement espacé de la région de contact intime de l'angle θ balayé par le rayon R_3, et $R = (R_4R_2)/(R_4-R_2)$ où R_2 et R_4 sont respectivement les rayons des surfaces sphéroïdales de la bille et de la coupelle, à proximité immédiate de la région de contact intime.

5. Prothèse selon la revendication 3 ou la revendication 4, dans laquelle R_2 est inférieur à R_3.

6. Prothèse selon la revendication 3 ou la revendication 4, dans laquelle R_4 est supérieur à R_1.

7. Prothèse selon la revendication 3 ou la revendication 4, dans laquelle $R_1 = R_4$.

8. Prothèse selon la revendication 3 ou la revendication 4, dans laquelle $R_2 = R_3$.

9. Prothèse selon l'une quelconque des revendications précédentes, dans laquelle les première et deuxième surfaces d'articulation dans la région de contact intime sont caractérisées chacune par une rugosité de surface moyenne centrale ne dépassant pas 0,1 micron.

10. Prothèse selon la revendication 9, dans laquelle les première et deuxième surfaces d'articulation dans la région de contact intime sont caractérisées chacune par une rugosité de surface moyenne centrale ne dépassant pas 0,025 micron.

11. Prothèse selon l'une quelconque des revendications précédentes, dans laquelle l'une des surfaces d'articulation de la bille ou de la coupelle est formée sur un rayon constant à la fois à l'intérieur et à l'extérieur de la région de contact intime et l'autre surface ne l'est pas.

12. Prothèse selon la revendication 4, dans laquelle R, en mètres, est compris entre 1 et 14.

13. Prothèse selon la revendication 4 ou l'une quelconque des revendications qui en dépendent, dans laquelle la configuration des surfaces dans la région sans contact à un emplacement espacé de la région de contact intime dudit angle θ, où θ est inférieur à 0,5 radian, est **caractérisée par** la relation $h = (R_1\theta)^2/2R \pm 3\ \%$.

14. Prothèse selon la revendication 4 ou l'une quelconque des revendications qui en dépendent, dans laquelle les surfaces dans la région sans contact à une position X sont **caractérisées par** la relation

$$g = (R_2-R_4)(1-D^2)^{1/2}+[R_4^{\,2}-(X^*-R_4D)^2]^{1/2}-[R_2^{\,2}-(X^*-R_2D)^2]^{1/2},$$

où $X^* = X-R_1(1-D)$, $D = \cos(\phi/2)$ et $R = (R_4R_2)/(R_4-R_2)$, et dans laquelle X, Y est situé dans un système de coordonnées X-Y ayant son origine au centre de la région de contact intime avec l'axe X perpendiculaire aux surfaces en contact de la bille et de la coupelle au centre de la région de contact intime, et où g est l'espace entre lesdites surfaces sphéroïdales dans la région sans contact mesuré parallèlement à l'axe Y à ladite position X.

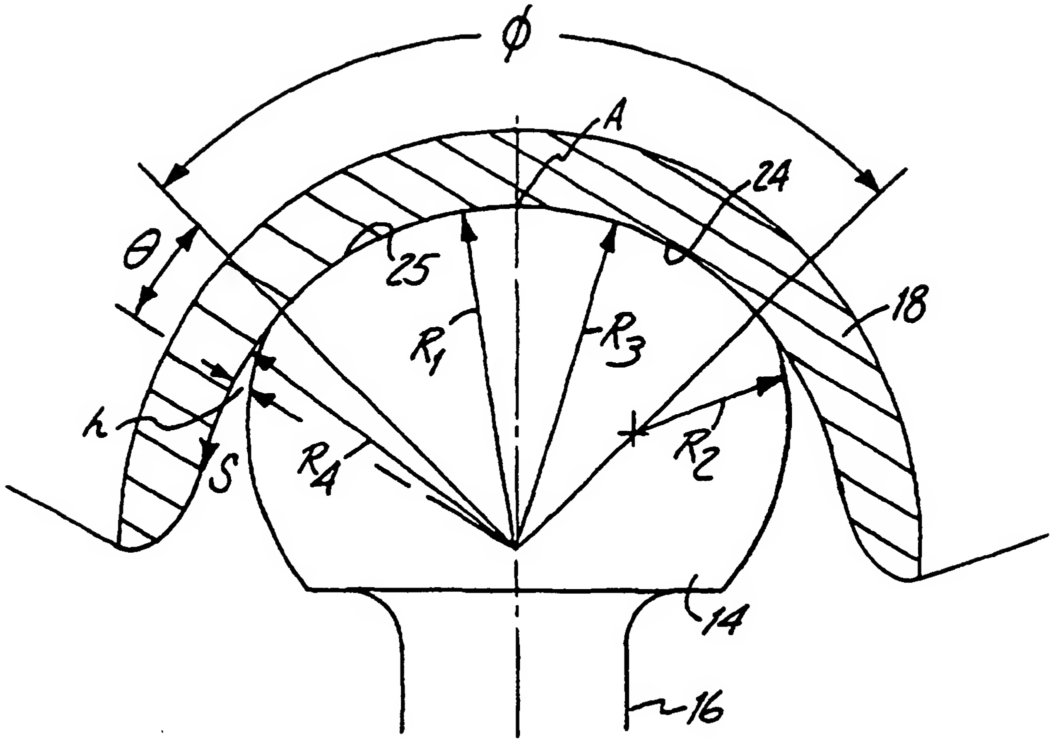

Fig. 1

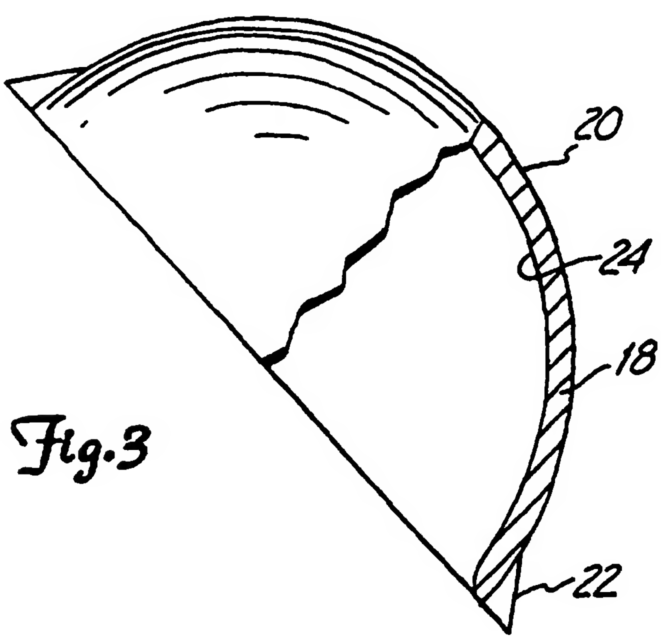

Fig. 3

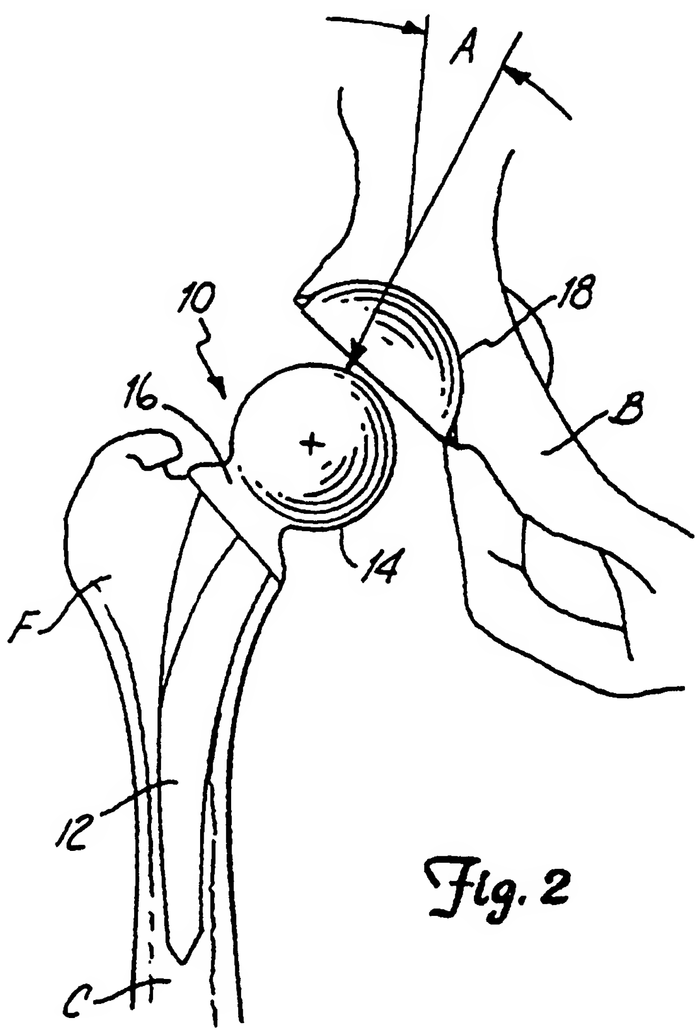

Fig. 2

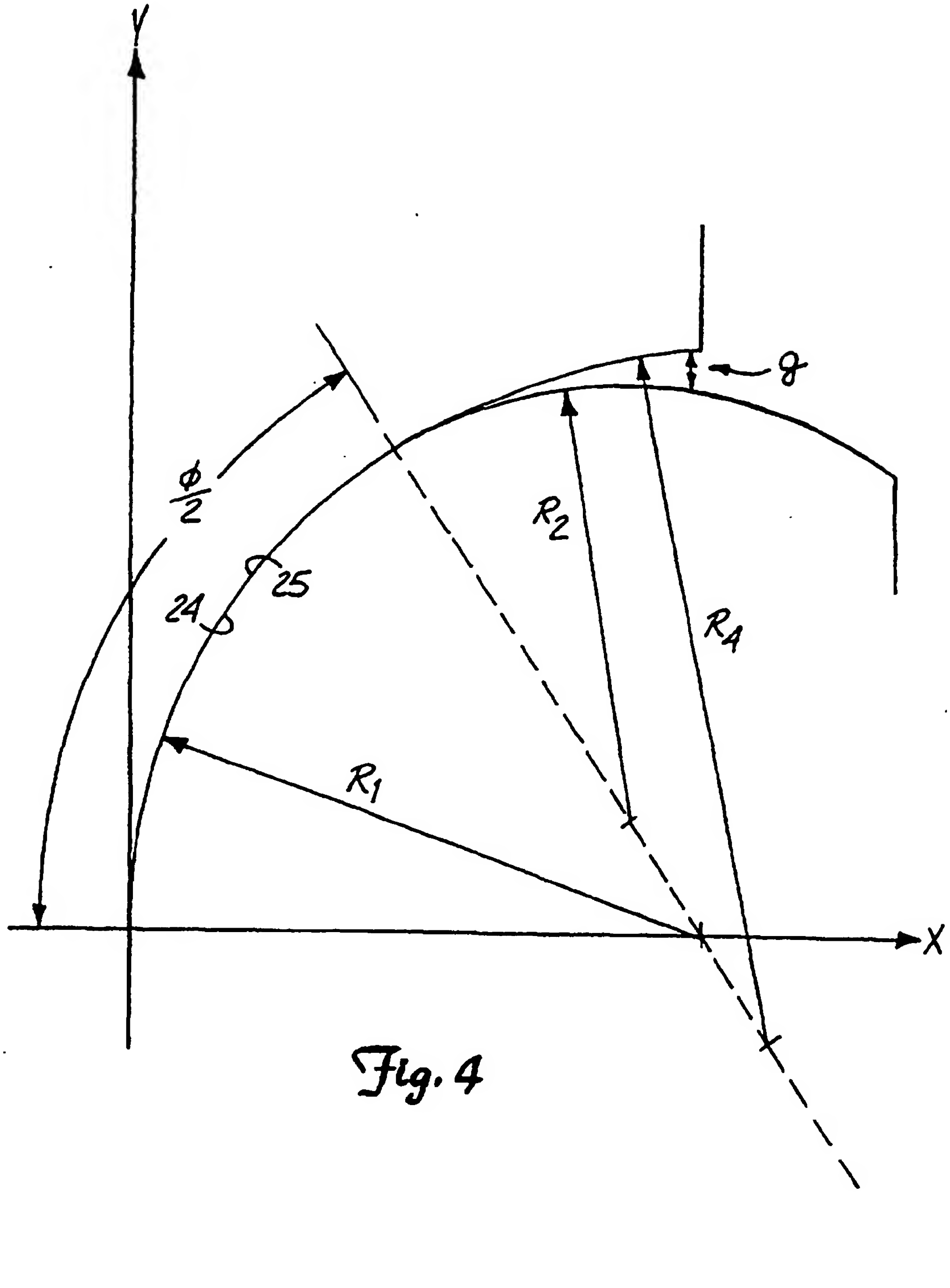

Fig. 4